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**APPLICATION NUMBER:** ***60/550,464***
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UNITED STATES PATENT AND TRADEMARK OFFICE · DEPARTMENT OF COMMERCE

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# PROVISIONAL APPLICATION COVER SHEET



This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53(b)(2).

**Docket Number:** MORV 8303US

## INVENTOR(s)/APPLICANT(s)

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## TITLE OF THE INVENTION (280 characters max)

METHOD AND DEVICE FOR CONTINUOUSLY FORMING OPTICAL FIBER CONNECTOR GLASS AND OTHER CLOSE TOLERANCE COMPONENTS

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## ENCLOSED APPLICATION PARTS (check all that apply)

☒ Specification — Number of pages [16] — ☒ Claiming Small Entity Status
☒ Drawings — Number of sheets [ 7 ]
☒ Claims — Number of sheets [ 7 ] — ☒ Abstract 1 sheet
☒ Unsigned Declaration and power of attorney — 1 sheet

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A check or money order in the amount of:

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The Commissioner is hereby authorized to charge any additional fees or credit overpayment under 37 CFR 1.16 and 1.17, which may be required by this paper to Deposit Account 162201. *Duplicate copies of this sheet are enclosed.*

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The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No
☐ Yes, the name of the Government Agency and the Government Contract Number are:

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Respectfully submitted,

J. Philip Polster
Reg. No. 24,739

Date: March 4, 2004

Express Mail No.: EV 383194733 US

SPECIFICATION

To All Whom It May Concern:

Be It Known That I, Vaughan Morrill, Jr., a citizen of the United States, and a resident of the City of Creve Coeur, State of Missouri, whose full post office address is, 11949 Charter House Lane, St. Louis, MO 63146 have invented new and useful improvements in

METHOD AND DEVICE FOR CONTINUOUSLY FORMING OPTICAL FIBER CONNECTOR GLASS AND OTHER CLOSE TOLERANCE COMPONENTS

## CROSS REFERENCE TO RELATED APPLICATIONS

Not applicable.

## STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not applicable.

## FIELD OF THE INVENTION

This invention relates to the production of high precision glass articles for optical fiber connectors and for other uses, and to a method of manufacture and a machine for carrying out the method.

## BACKGROUND OF THE INVENTION

Previous methods for making high precision glass tubing employ the well known redraw technique where in a close tolerance redraw blank tube is drawn down to a smaller size to make such articles as glass ferrules. See for instance U.S. Patents Numbers 4,850,670, 5,295,213, 5,314,517, and 6,098,428.

In all of the various redraw processes, the dimensional characteristics of the tubular starting blanks substantially control all of the final dimensions of the redrawn tubing. Such things as roundness, concentricity of inner bore to outer diameter and the ratio of inner bore size to the outer diameter can not be changed during redraw, and as a consequence, the greatest proportion of the cost to make redraw tubing lies in the original blank preparation costs and the very inefficient batch type, non-continuous redraw operation.

My previous method of making high precision glass tubing, described in U.S. Patent 3,401,028, employs bulky and expensive equipment and generally is incapable of forming glass tubing having the high precision required for many modern applications, such as the

manufacture of glass ferrules or connectors for optical fibers. These applications may require precise inside and outside dimensions, wall thickness, roundness, and concentricity, all measured in nanometers, for example one hundred nanometers or less, sometimes ten nanometers or less.

The patents mentioned above are hereby incorporated by reference.

## SUMMARY OF THE INVENTION

The present invention provides a method whereby a high precision redraw blank is not used but rather continuously drawn or cut lengths of commercial grade round glass rod are used as the starting material. This invention provides a way to extrude and pull molten glass tubing and rod under pressure from a die while errors in all the critical dimensions of the resulting product are continuously corrected by an automatic feedback system. As a result of this ability to change dimensions on the fly, it is no longer necessary to build into the starting material extremely costly high precision dimensional characteristics.

The elimination of a high precision starting blank and the ability to run continuously eliminates as much as 90% or more of the cost of making redraw tubing and gives a large commensurate improvement in the high precision size tolerances.

The articles made by continuously drawing glass tubing according to this invention, are controlled for outside diameter, inside diameter, roundness, wall thickness and axial center of inside diameter in relation to the outside diameter by both automatic and manually adjusted parameters.

Both hollow and solid glass articles can be manufactured by utilizing the teachings of the instant invention. Single bore and double bore, as well as multi-bore tubing for such applications as fiber optic connector ferrules and sleeves and photonic band gap materials can

be made with tolerances measured in nanometers, typically less than 100 nanometers, sometimes on the order of ten nanometers.

In the following description, the term "draw down" is used herein to describe the semi-molten shape of glass emerging from the melter. The draw down in the preferred embodiments is a hollow shape emerging from a die at the outlet of the melter and having a ratio of inner dimension to outer dimension generally the same as the finished glass tube produced by the preferred process and apparatus of the invention. The term "cone" is used herein to describe a hollow part. Although such parts are shown as at least partially conical in the preferred embodiments, these parts may include or consist of other shapes, such as cylindrical, prismatic (of various cross-sectional shapes) or pyramidal.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1A, 1B, 1C, and 1D show an overall longitudinal partial cross-section of one illustrative embodiment of apparatus according to the invention for carrying out one illustrative embodiment of the methods of the invention.

Figure 2 is a detailed cross-section of an input portion of a melting chamber of the apparatus of FIGS. 1A-1D.

Figure 3 is an overall longitudinal partial cross-section of another illustrative embodiment of apparatus according to the invention; sections 3A, 3B, 3C, and 3D corresponding to FIGS. 1A, 1B, 1C, and 1D.

Figure 4 is a detailed cross-section of a melter portion 3B of FIG. 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following detailed description illustrates the invention by way of example and not by way of limitation. This description will clearly enable one skilled in the art to make and use

the invention, and describes several embodiments, adaptations, variations, alternatives and uses of the invention, including what I presently believe is the best mode of carrying out the invention. As various changes could be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in this description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

## EXAMPLE 1
## FIRST EMBODIMENT OF APPARATUS

In Figure 1, reference 1 designates a solid round glass rod cut to lengths with square ends being fed to the rod feed system. Pulleys 2, 3, 4 and 5 support the incoming glass rod and hold it on the center of the rod feed system as the rod is being pushed forward by motor driven roller 6. Switches 7, 8, 9 and 10 are activated by the rod end as it passes by each switch to start timers 11, 12, 13 and 14. These timers pneumatically lift rollers 15, 16, 17 and 18 momentarily and sequentially to allow the rod ends to pass through pinch rollers 15, 16, 17 and 18 and stepper motor drive rollers 19, 20, 21 and 22, so that rod ends will not crack during their passage through the pinch rollers and drive rollers. The pinch rollers are activated by air cylinders 23, 24, 25 and 26, which are controlled by electric solenoids 27, 28, 29 and 30 and air pressure regulators 31, 32, 33 and 34, all controlled by electric pneumatic control box 35. Stepper motor drives to pinch rollers 19, 20, 21 and 22 are controlled by drive 36 so that they all turn at exactly the same speed. The speed of these rollers is controlled by the output voltage of controller 38, which is connected to laser size micrometer 37. Numeral 75 denotes the laser micrometer beam that continuously measures the outside diameter of draw down 73 and sends a signal to controller 38 and stepper motors 19, 20, 21 and 22 to adjust the rod feed motor speed

to keep the draw down diameter 73 constant as it issues from die 68 and is pulled by pull rollers 69. The laser micrometer 37, which generates measuring beam 75, is held by bridge 76 on opposite sides of glass covered draft box 77. Bridge 76 can be moved by micrometer screw 78 to position laser micrometer 37 as close as possible to die 68 so that there is minimal delay in seeing changes in the draw down 73 size. Funnel tube 40 is held in place by bracket 39, which is locked in place after glass-melting tube 47 is at running temperature and will not undergo any more thermal expansion. Rod 106 is adjusted to hold electrodes 60 and 61 in a fixed position after heat up to running temperature. Tube 40 is heated by muffle furnace 42 and its temperature is controlled by thermocouple 41 in combination with controller 58 and SCR 59. There are four strap electrodes 43 set 90° apart and four strap electrodes 52 set 90° apart that are connected to main power electrodes 60 and 61 coming from transformer 64. Transformer 64 is controlled by thermocouple 48, controller 65, and SCR 66. Constant voltage power supply 67 prevents sudden line voltage changes from affecting melter 47 temperature. The melter 47 is resistance heated by transformer 64 between electrodes 60 and 61. Melter tube 47 is approximately 30% thicker than end portions 46 and 49 to cause these areas to run hotter than center section 47 to make up for heat loss by the end straps 43 and 52, as glass rod 1 is pushed through hot cone 40, center guide sleeve 44 and through restriction section 46. The tube 40 preheats the rod 1 sufficiently to soften the exterior portions of the rod 1 upstream of the restriction 46. The restriction 46 maintains the rod 1 on center. The restriction 46, which has a reduced section about 0.5% to about 5% smaller in diameter than the smallest round glass rod 1 being fed to the input cone 40, melts the rod and forms a continuous seal between the rod and the wall of the restriction 46. As shown in FIG. 2 at 141, a small ring of molten glass may form on the upstream side of the restriction 46. That ring is drawn through the restriction 46 by the

rod 1, thereby preventing entrainment of air with the rod. The continuous seal formed between the rod 1 and the restriction 46 also prevents flow of glass from the melting chamber back into the input cone 40 through the restriction 46 and allows for relatively high pressures to be built up in melter 47 and outlet section 53. This pressure forces molten glass to exit end die 68 and be pulled away by pull roller system 69. The pressure in the melter 47 also prevents expansion of any trapped air in the glass and prevents the formation of air bubbles or air lines in the finished product. The viscosity of the extruded glass is high enough so that gravitational forces do not cause any significant sag or deformation.

A hollow cone 51 is positioned in the outlet section 53 of the melter 47. The hollow cone 51 is formed of a drawn hollow tube having a cone machined at its downstream end. The conical downstream section of the cone 51 is positioned within the die 68 and forms the bore of the draw down 73 and thus of the final tube 110. The downstream end of the hollow cone 51 is preferably positioned near the outlet orifice of the die 68. The hollow cone 51 communicates with the atmosphere. The upstream, cylindrical, end of hollow cone 51 is connected to a nano meter actuator 54 through a gland 50 in the outlet section 53 of melter 47.

Gland 50 is kept at a semi-molten temperature that will not leak glass, but still allows motion of the inner hollow cone 51 to be adjusted in the X and Y directions by nano meter actuator 54 to adjust the concentricity of the bore of the final glass tube 110, and in the Z direction by adjustable slide rods actuated by micrometer 55 to adjust the size of the bore of the final glass tube. The gland 50 is typically formed by an opening in the wall of the chamber 53 about 0.02 to 0.05 mm larger than the outer diameter of the hollow cone 51. The gland 50 allows the cone 51 to pivot and slide in the gland.

The temperature of outlet tube 53 is controlled by split clamshell furnaces 56 and 57, thermocouples 58 and 59, controllers 69 and 71 and SCR 70 and 72. The two furnaces are split so that different temperatures can be set above and below tube 53 to obtain better roundness in the draw down area 73. Four setscrews 74 placed 90° apart are used to adjust the centering of the two clamshell furnaces around tube 53 to further improve roundness of the draw down area 73.

Draft box 77 can be moved in and out by air cylinder 79 to hold ring 80 and ring 81 tight against die cap 68 and against tube 53 so that it will not leak glass. Glass tube 80 is sealed by ring 82 and 81 so that a draft will not be created in draft box 77. Split hinged water cooled box 83 prevents drafts from disturbing glass dimensions before it has set to final size as it is being pulled by pull rollers 69. Laser micrometer 84 is used to sense the final outer diameter of glass tube 110 as the glass is being pulled through guide rollers 105.

The pull roller system 69 is operated so that the two stepper motors 85 and 86 drive rubber cog belts 87 and 88 at exactly the same speed while they are held in a spring-loaded engagement of the glass being pulled by springs 89. Laser 84 monitors the outside diameter of the glass 110 after it has solidified and sends a signal to controller 99 to vary the speed of the pull rollers to keep a final fixed diameter.

Constant temperature water cooling comes from tank 100 and pump 101 through chiller 83 to electrode cooling ring 102 to electrode cooling ring 103 and back to chiller 104 and to tank 100 for constant temperature conditioning and back to pump 101.

The five process instruments are Honeywell UDC-3300 Digital Controllers, Fort Washington, PA. The stepper motors and nano positioning equipment were Aerotech, Pittsburgh, PA. The laser micrometers are Keyence LS-5000 series made by Keyence

Corporation of America, Woodcliff Lake, New Jersey. There are several manufacturers who make this type of equipment so the ones mentioned are not unique.

## EXAMPLE 2
## METHOD USING FIRST APPARATUS

For process development purposes, all metal parts that were in contact with molten glass were made of 310 stainless steel made by Rolled Alloys, Temperance, Michigan.

The glass rod feed stock was 11 mm SG 10 glass, made by Sylvania, Versailles, KY. Outer diameter tolerance was ±0.15 mm. The input cone 40 on the melter was 11.5 mm in diameter, and the restriction 46 was 10.72 mm in diameter. The outlet orifice diameter was 12.50 mm, and the hollow inner cone 51 was 1.0 mm in outer diameter at its downstream end, 6.3 mm in outer diameter through most of its length, and 0.63 mm in inner diameter through its entire length.

After heating the machine to start feeding glass rod through the input cone 40 with input furnace at approximately 980° C, the rod was fed at a sufficient rate to make 1.25 mm O.D. tubing with a 125 micron I.D. bore at a pull rate of eight meters per minute. The glass melting tube 47 was approximately 1050° C, the clamshell furnaces 56 and 57 were approximately 1020° C and the finished tubing had size tolerances well within those required for fiber optic glass ferrules.

The adjustments to the position of the hollow cone 51, taken with the rate at which the rod 1 is pushed, the rate at which the final glass tube 110 is pulled, and the temperature of the melting chamber outlet section 53, give unprecedented control of the dimensions, roundness and concentricity of the final tube 110, all of which can be controlled to within 100 nanometers or better if required for a particular application.

The method and apparatus of the present invention have numerous advantages over redraw techniques. They can reduce the cost of manufacture by 90% or more. The use of a high pressure extrusion process (believed to be over ten pounds per square inch or 69 kilopascals) allows glass to be made continuously without airlines, and to give much closer dimensional control and sharper shapes than redraw. Square corners and flat surfaces are easily formed. The method and apparatus provide the ability to run continuously from a source of glass rod such as made by the well-known Vello process, thereby eliminating the problems caused by welding rods or preforms. It will be understood, however, that the relatively inaccurate rods formed by the Vello process may, if desired, be welded together to form a continuous glass feed, or the rods may, if desired, be reformed to closer dimensions by melting and extruding them from a die. Because the present invention positions both the rods and the finished tube or other shape horizontally, it eliminates the need for towers.

EXAMPLE 3
SECOND EMBODIMENT OF APPARATUS

A modification of the machine of Example 1 is shown in FIGS. 3 and 4.

In section 3A of FIG. 3, reference numeral 201 designates a solid round glass rod cut to lengths with square ends being fed to the rod feed system by motor and drive rolls 206. As the preceding rod passes photocell 212, a signal is given to motor 206 to advance another rod. As the end of this new rod 201 passes photocells 207, 208, 209, and 210, air cylinder and motor drive pinch rolls 215, 216, 217, and 218, respectively, lift up and down to prevent breaking the ends of the square cut glass rods as they pass through the pinch rolls. Control box 235 in conjunction with the photocells actuate the pinch rolls at the proper time. Motors 219, 220, 221,

and 222 are rotated at a controlled speed by the output of a laser 237 and a thermocouple TC2 connected to control box 236. The motors operate in such a way as to keep a constant volume of molten glass being extruded through outlet cone 68. First, the drive motor pinch rolls 219, 220, 221, and 222, all running in synchronous rotation, are caused to speed up or slow down by the rate at which glass rod is fed into inlet cone 40 to keep a constant temperature at thermocouple TC2 through control box and motor speed control 236. Second, laser 237, reading the diameter of the draw down at the outlet cone 68, can feed a further signal to the drive motors through control box 236 to make a final adjustment of size. Control box 236 can accept the two inputs and adjust its output by giving equal weight to the two inputs or, alternatively, in accordance with other algorithms as is well-known in the control art.

In section 3B, actuator 223 centers and guides the rod 201 into the inlet cone 40, which is heated by furnace 42 and temperature controlled by a fixed power input from control box 236. Thermocouple TC1 is used to adjust furnace 42 to a desired temperature. In this embodiment, the inlet of the chamber 247 is tapered at restriction 46 from an inner diameter of 0.485" to an inner diameter of 0.422", at a conical angle of about 1° (included angle of about 2°), and the remainder of the chamber 247 is of uniform cross-sectional area. Both the restriction 46 and the entire first portion of the chamber 247, in this embodiment, are thus smaller in diameter than the smallest rod 201 which will be fed into the chamber 247. Chamber 247 is resistance heated by transformer 64 and electrodes 245 and 243. Thermocouple TC3 is used through control box 236 to set up the constant power to chamber 247 to establish a desired temperature. Strap electrodes 43 at the inlet end are made narrower than strap electrodes 52 to establish a thermal gradient between the ends of the chamber 247. Inner cone 51 is supported near its open rearward end by an actuator 54 and is supported inside the chamber 247 by four

spokes 251. Actuator 54 can move inner cone 51 radially through semi-molten gland 50 to position the inner cone 51 on the exact center of outlet cone 68 and also longitudinally to control relative sizes of the inner diameter (ID) and outer diameter (OD) of the glass extruding from end cone 68. The temperature of the outer end sleeve 53 is controlled by split clamshell furnaces 56 and 57, through thermocouples TC4 and TC5 and control box 236. Laser 237 looks at the outside diameter of the draw down glass issuing from outlet cone 68 through draft box 77 and sends signals to control box 236 to make final changes in rod feed motors 215, 216, 217 and 218 to keep draw down glass size constant. Tubing 236 is pulled through water cooled hinged box 83, over support pins 224 through rollers 105 by pull rolls 69 and pushed through deflection rolls 238. By changing the speed of the pull rolls 69 with control box 255, the OD of the glass can be adjusted to the desired size. Laser 84 measures the OD of the tube 236 and signals actuator 220 through control box 99 which way to deflect the tube 236 between rollers 238. Moving the rollers 238 acts as a classifier for diverting the tube 236 to an "accept" 232, "reject high" 230, or "reject low" 234 direction, and collecting the three classifications of tube by the use of a cutter to separate them.

The constant temperature water cooling system flows continuously from pump 101 through pipe 246, through hinged box 83, through pipe 244, to electrode cooling ring 248, through pipe 242, to electrode cooling ring 241, through pipe 240 and into constant temperature chiller tank 100, where it is returned to pump 101.

Microscopes 253, set at a 90° angle to each other, are used to adjust the inner capillary bore for exact center of the issuing molten glass tube 236, and to adjust the relative size of the inner capillary bore by manipulating actuator 54 while the machine is in operation and semi-molten glass gland 50 is hot.

It will be seen that major changes in the design, as compared with the design of Example 1, are as follows. Control of the feed rate of the rod is achieved by measuring the temperature of the inlet cone in thermal proximity to the restriction, illustratively just downstream of the restriction 46 at the inlet of the melting chamber 247. Because glass in contact with the inlet cone cools the heated inlet cone, instantaneous changes in the temperature of the cone are indicative of instantaneous changes in the diameter of the glass rod being fed into the melting chamber. It has been found that by placing a thermocouple on the outside of the inlet cone, control of the size of the tube formed at the outlet of the device can be controlled extremely precisely. Although the precise position of the thermocouple may be varied somewhat, around the restriction 46, it is preferably near the junction of the input cone and the restriction. The thermocouple TC2 and controller 236 maintain a constant preset temperature at the thermocouple TC2 by varying the speed of rod input motors 219, 220, 221, and 222. If the apparatus and the rod 1 are kept in a controlled temperature environment, this control system maintains a constant mass of glass flowing through the melter 247, hence a constant outer and inner diameter of the finished glass tube.

The modified machine has been further changed by reducing the effective inner diameter of the entire melting chamber to be less than the smallest diameter of the rod 1, preferably substantially equal to the inner diameter of the restriction 46. Because the hollow cone 51 fills a part of outlet section 53 of melter 247, the diameter of the outlet section is slightly larger than the diameter of the inlet section of melter 247. This arrangement has been found to minimize air bubbles in the finished tube. It has also been found that making the inlet section of the melter 247 below the outlet section 53 helps to minimize air bubbles in the finished tube.

In view of the above, it will be seen that the several objects and advantages of the present invention have been achieved and other advantageous results have been obtained. As numerous variations will be apparent to those skilled in the art, the foregoing disclosure is to be understood as exemplary and not as limiting the scope of the invention, whose scope is to be determined solely by the following claims.

Merely by way of example of changes that could be made, to produce glass ferrules from 7740 Borosilicate glass, a platinum alloy such as PT-20RH is preferred for all the metal parts that come into contact with molten glass, and the temperatures on the various parts of the apparatus as stated above would all be increased by somewhat more than 250° C.

The ratio of the outside diameter to inside diameter of the tubing produced by the example was primarily for illustrative purposes and not to limit in any way what this ratio might be on any particular production run. Other shapes, such as rectangular tubing may be produced with a rectangular die 68 and rectangular hollow cone 51. By eliminating or moving rearward the hollow cone 51, solid glass rods of any cross section may be formed to closer tolerances than can be mass produced presently. A cluster of hollow cones 51 may also be utilized to produce tubes with multiple lumens. Such a cluster could be of different diameters as well as the same diameter. This approach makes possible the production of a wide variety of photonic band gap or photonic crystal fibers and multiple-fiber connectors.

By setting the rubber cog belts at an angle to each other in the horizontal plane, the round glass can be caused to rotate as it is pulled from the die, if so desired.

The use of the laser measurement device that responds to glass outside diameter after the glass has solidified may not in all cases be needed. When utilized, a measurement of the finished glass tube may be made at any point after the tube leaves the outlet orifice of the

melter. Preferably, the measurement of the inlet temperature is utilized to control the push rate of the feed rod, and measurement of the finished tube is utilized to control the pull rate on the tube. It will be understood, however, that these measurements can be utilized for both purposes, and algorithms will immediately occur to those skilled in the art for mixing the measurement signals to control both push rate and pull rate. Because the system has very little hysteresis, the amount of control required is greatly reduced. It will further be understood that although it is highly desirable to maintain the temperature of the melting chamber constant, it is possible to adjust both push and pull rates to compensate for variations in temperature.

The glass size measuring and control system may use other than lasers to control the final glass size.

The glass melting portions of the apparatus can be heated by either resistance or radiant methods, or by other methods known in the art.

The input cone 40 may be cylindrical; and the sleeve 44 may be eliminated if the feed stock 1 is sufficiently straight. The shape of the input cone 40 may be varied to accommodate the shape of the feed stock.

The diameter of the rod at the restriction 46 may be determined in other ways. For example, a strain gauge mounted to the restriction or its mountings could be utilized. The torque required to drive the rod may also be utilized to determine the size of the rod at the restriction. The diameter of the rod may be directly determined at a point before the restriction, as by an array of laser interferometers, and the rate of feed varied in accordance with the predicted time of arrival (using a shift register) of variations in diameter at the restriction. The illustrative method of measuring temperature at the restriction is a more direct way of determining mass at the inlet of the chamber, however, and is therefore presently preferred.

Although the illustrative machine preferably utilizes glass, it will be understood that in principle the machine and method may be used for forming any heat-softenable material.

These variations are merely illustrative.

CLAIMS:

1. A method of forming a continuous glass shape of uniform cross-section, the method comprising a step of pushing a glass rod into a melting chamber, a step of melting the rod in the chamber, a step of extruding molten glass in the chamber through a die to form a draw down, a step of pulling the glass draw down to form said shape, a step of measuring at least one dimension of the draw down or the shape, and a step of varying at least one of the rate of pushing the rod or the rate of pulling the glass object in response to the measuring step.

2. The method of claim 1 wherein the measuring step measures an outside dimension of the shape.

3. The method of claim 1 wherein the measuring step measures an outside dimension of the object.

4. The method of claim 3 wherein the step of feeding the glass rod is continuously varied in response to the measuring step.

5. The method of claim 1 wherein the step of feeding the glass rod is continuously varied in response to the measuring step.

6. The method of claim 1 wherein the measuring step measures both an outside dimension of the object and an outside dimension of the shape, and wherein the step of feeding the rod is varied in response to the measured dimension of the object and the step of pulling the object is varied in response to the measured dimension of the shape.

7. The method of claim 2 wherein the measurement of the dimension of the shape occurs after the shape has attained substantial dimensional stability.

8. The method of claim 1 wherein the rod and the shape are both substantially horizontal throughout the method.

9. A method of making a glass shape comprising a step of providing a heating chamber, the heating chamber having a single inlet and a single outlet, a step of pushing a solid glass rod into the inlet and a step of pulling a shape from the outlet.

10. The method of claim 9 wherein the inlet comprises a heated cone, the cone melting the exterior of the rod and forming a molten glass seal at the inlet.

11. A method of making a glass shape comprising a step of providing a heating chamber, the heating chamber having a single inlet and a single outlet, and a step of pushing a solid glass rod into the inlet, wherein the inlet comprises a heated cone, the cone melting the exterior of the rod and forming a molten glass seal at the inlet.

12. The method of claim 11 wherein the heated cone is exterior of the chamber.

13. The method of claim 11 wherein the inlet has a diameter slightly smaller than the diameter of the rod.

14. The method of claim 13 wherein the rod has a diameter which varies at least 0.5% and no more than 5%.

15. The method of claim 14 wherein the inlet has a diameter 0.5% to 5% smaller than the smallest diameter of the rod.

16. A method of continuously making a glass shape comprising a step of heating glass in a chamber, the chamber having an inlet and an outlet, and a step of feeding solid glass continuously to the inlet of the chamber.

17. The method of claim 16 wherein the process comprises withdrawing molten glass through the outlet.

18. The method of claim 17 wherein the molten glass is pulled away from the outlet.

19. The method of claim 16 wherein the solid glass is fed generally horizontally into the chamber.

20. The method of claim 16 wherein the solid glass comprises a plurality of solid glass pieces in abutting relationship.

21. The method of claim 16 wherein at least a portion of each glass piece is pushed into said inlet by a succeeding piece.

22. The method of claim 21 wherein the glass pieces are solid rods.

23. The method of claim 16 further comprising a hollow cone extending from the vicinity of the outlet, through a wall of the chamber, the method comprising drawing air through the hollow cone to form a glass tube.

24. A method of feeding glass into a melting chamber comprising guiding a solid glass piece having a generally uniform cross-section through a heater to soften an outer portion of the piece, and thereafter forcing the glass piece through a restriction smaller than the cross-section of the piece into the melting chamber.

25. The method of claim 24 wherein the melting chamber has an outlet which is cooler than the major portion of the melting chamber.

26. The method of claim 25 wherein forcing the glass piece through the restriction produces a softened glass seal at the restriction and produces pressure within the melting chamber.

27. An apparatus adapted to form a hollow tube, the apparatus comprising a heated chamber having an outlet, a die in the outlet, and a hollow cone extending from the vicinity

of the outlet, within an inside dimension of the die, through a gland in a wall of the chamber.

28. The apparatus of claim 27 further comprising an adjustment device operatively attached to a part of the hollow cone outside the chamber.

29. The apparatus of claim 28 wherein the adjustment device controls both pivotal movement and sliding movement of the hollow cone.

30. The apparatus of claim 27 wherein the chamber is filled with molten glass, the glass being cooler adjacent the gland and adjacent the die than the average temperature of the glass in the chamber, the gland forming a seal of glass between the inner cone and an opening in a wall of the chamber.

31. An apparatus for feeding glass rod sections comprising a plurality of feed drives, at least one of the feed drives being biased into engagement with the rod, a sensor for detecting rod section ends, and a mechanism for varying the bias of the at least one feed drive in response to the sensor to protect the rod ends.

32. The apparatus of claim 31 wherein the rod ends are abutting.

33. A method of controlling the rate at which a rod of heat-softenable material is fed through a heated restriction, the restriction softening at least an outer portion of the rod, the method comprising a step of determining changes in temperature at the restriction, and a step of controlling the rate of feeding the rod in response to changes in temperature at the restriction.

34. The method of claim 33 wherein the rod is solid.

35. The method of claim 33 wherein the rod is made of glass.

36. The method of claim 33 wherein the step of controlling the rate of feeding the rod maintains a constant mass per unit time of the material passing through the restriction.

37. The method of claim 34 wherein the restriction is the inlet of a melting chamber.

38. The method of claim 37 wherein the melting chamber includes an outlet, the material forming a draw down at the outlet.

39. A method of forming a shape of a heat-softenable material, the method comprising a step of feeding a solid rod of the material into a heated chamber through a heated restriction, a step of determining changes in temperature at the restriction, and a step of controlling the speed of feeding the rod in response to changes in temperature at the restriction.

40. A method of forming a continuous glass shape, the method comprising a step of feeding a glass rod into a melting chamber through a restriction, a step of determining a diameter of the glass rod being fed into the chamber by measuring a temperature at the restriction, and a step of controlling the speed of feeding the glass rod in response to the measured temperature at the restriction to control the rate of feed of glass into the chamber.

41. A method of forming a continuous glass shape of uniform cross-section, the method comprising a step of feeding a glass rod into a melting chamber through a restriction, a step of determining a diameter of the glass rod being fed into the chamber by measuring a temperature at the restriction, and a step of controlling the speed of feeding the glass rod in response to the measured temperature at the restriction to maintain a constant flow of glass into the chamber.

42. A method of forming a continuous glass shape of uniform cross-section, the method comprising a step of feeding a glass rod into a melting chamber through a restriction, a step of determining changes in a temperature at the restriction, and a step of controlling the rate of flow of molten glass through the chamber in response to the changes in temperature at the restriction.

43. The method of claim 42 wherein the step of controlling the rate of flow comprises controlling the rate of feed of the rod.

44. The method of claim 42 wherein the step of controlling the rate of flow comprises controlling a rate of withdrawing molten glass from the chamber.

45. A method of forming a continuous glass shape of uniform cross-section, the method comprising a step of feeding a glass rod into a melting chamber through a restriction, a step of pulling the glass shape from the chamber, a step of determining changes in a temperature at the restriction, and a step of controlling at least one of the rate of feeding the glass rod and the rate of pulling the glass shape in response to the changes in temperature at the restriction.

46. The method of claim 45 wherein the restriction has a diameter no greater than the smallest diameter rod fed into the restriction.

47. A method of forming a shape of a heat-softenable material, the method comprising a step of feeding a solid rod of the material into a heated chamber, a step of determining changes in the diameter of the rod, and a step of controlling the speed of feeding the rod in response to changes in the diameter of the rod.

48. The method of claim 47 wherein the step of determining changes in the diameter of the rod comprises determining a change caused by entry of the rod into a restriction at an inlet of the chamber.

49. The method of claim 48 wherein the change is a change in temperature.

50. The method of claim 48 wherein the change is a change in force on the rod or the restriction.

51. A method of forming a shape of a heat-softenable material, the method comprising a step of feeding a solid rod of the material into a heated chamber, a step of pulling the shape from the chamber, a step of determining changes in the diameter of the rod, and a step of controlling at least one of the rate of feeding the rod and the rate of pulling the shape in response to changes in the diameter of the rod.

52. The method of claim 51 wherein changes in the diameter of the rod are detected by changes in temperature at an inlet side of the chamber.

53. A method of controlling a quantity of glass fed through a molten glass-wetted gland, the method comprising pushing a glass rod through a heated passage defined by at least one passage wall to melt an outer portion of the rod, the melted glass contacting the passage wall and forming a seal with the wall, and a step of sensing cooling of the wall caused by the melted glass contacting the wall.

54. A method of continuously making a glass shape comprising a step of pushing glass into an inlet of a chamber, the chamber being heated by spaced electrodes attached to a wall of the chamber, and a step of pulling the glass shape from an outlet of the chamber.

ABSTRACT OF THE DISCLOSURE

A method and device for making high-precision glass forms. A glass rod is pushed into a heated chamber and the glass form is pulled from the chamber. Preferably, both the push rate and the pull rate are controlled. Fiber optic glass ferrules and other components manufactured by the use of this invention have precision dimensions that fall well within the tight dimensional tolerances required for ferrules and others.

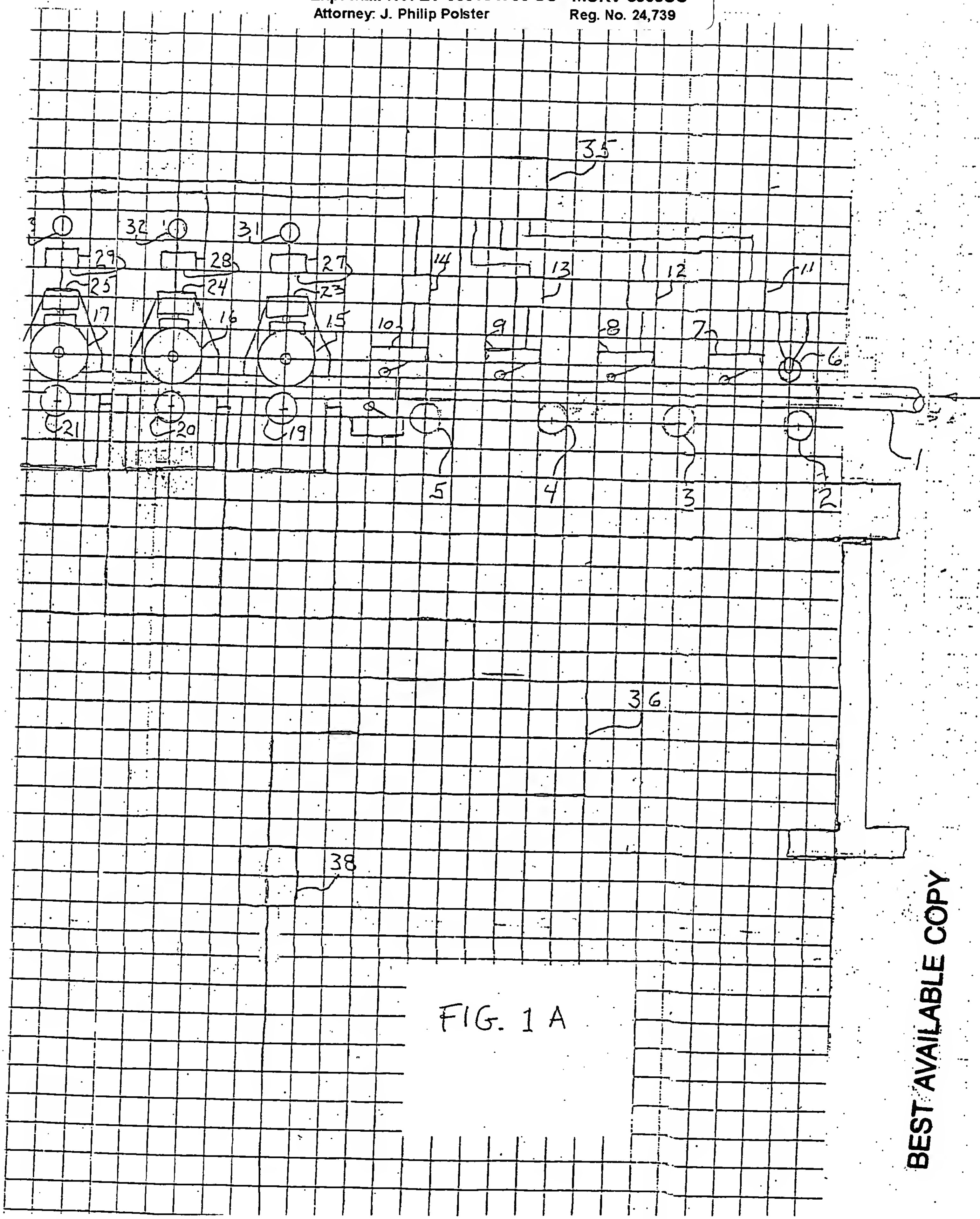
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FIG. 1A

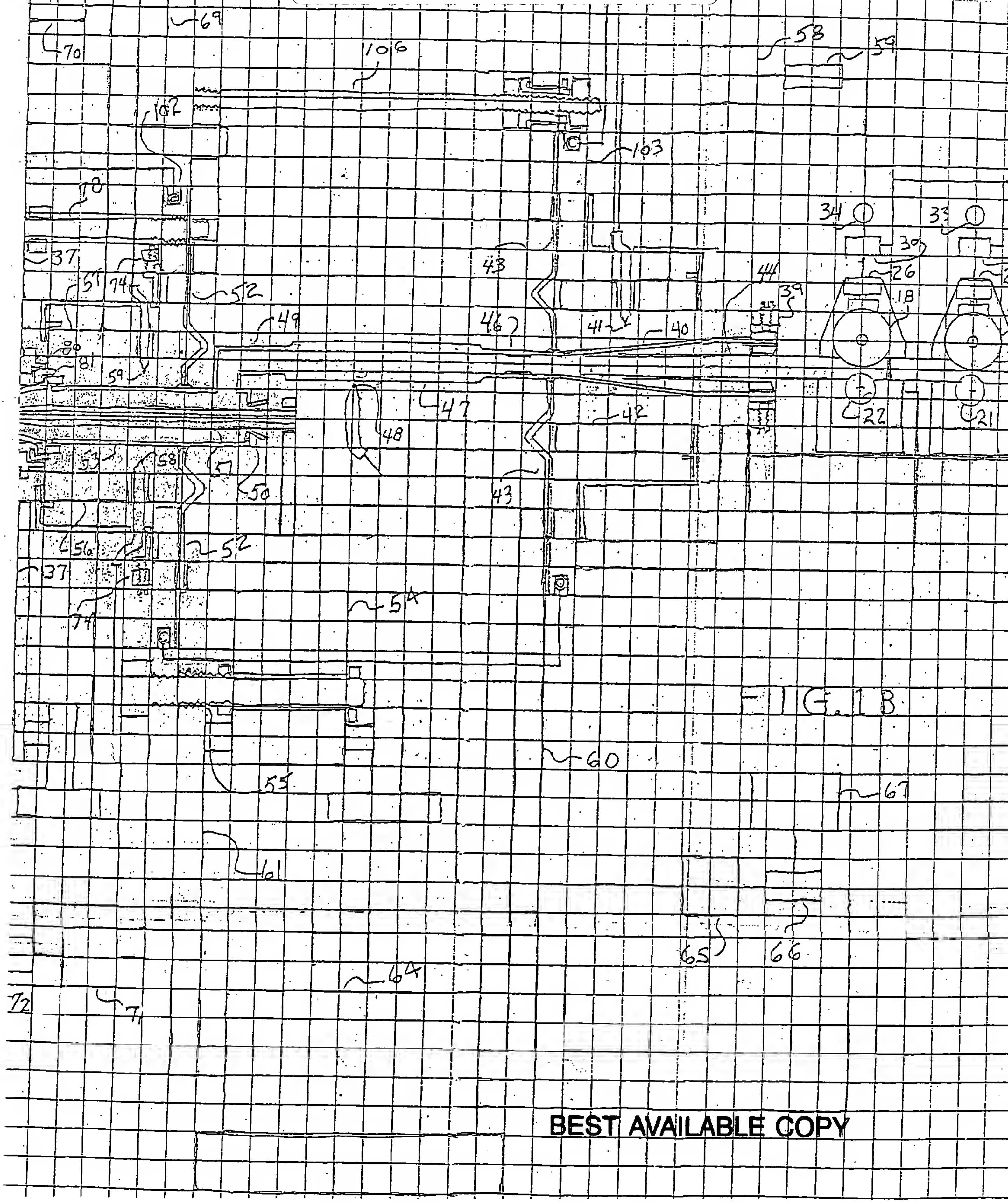
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FIG. 1B

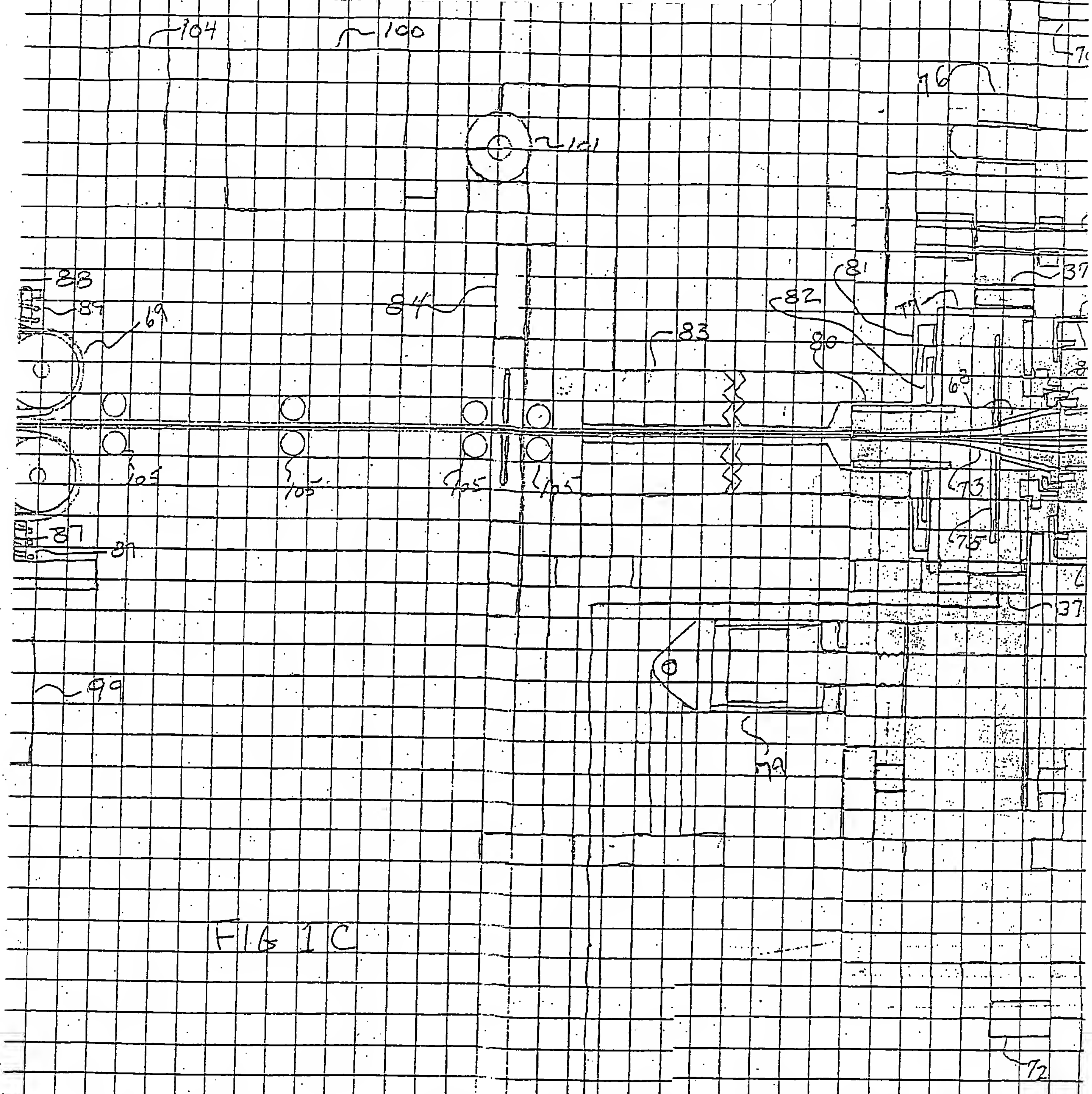
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FIG 1C

METHOD AND DEVICE FOR CONTINUOUSLY FORMING OPTICAL FIBER CONNECTOR..........
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Attorney: J. Philip Polster Reg. No. 24,739

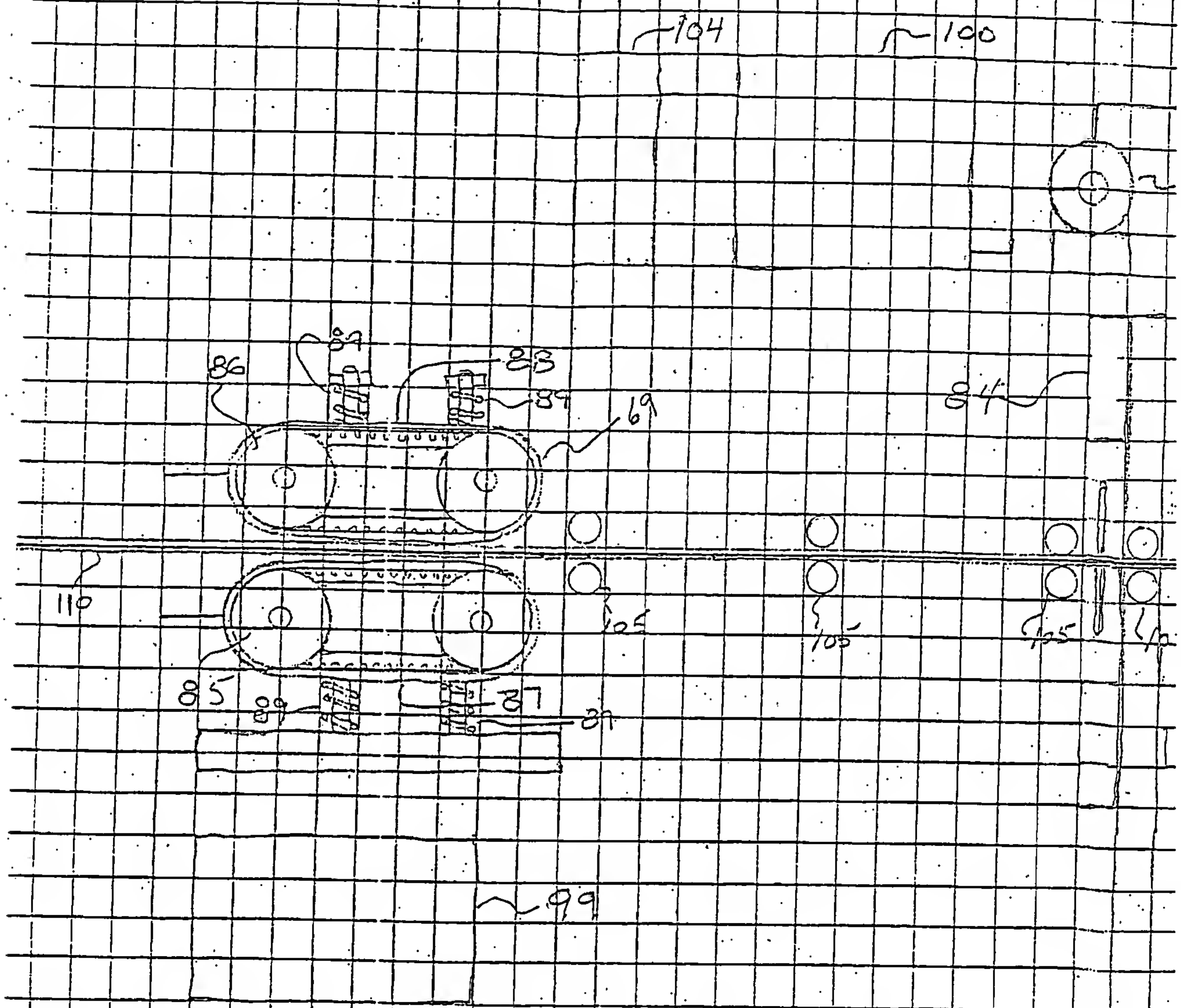


FIG. 1D

METHOD AND DEVICE FOR CONTINUOUSLY FORMING OPTICAL FIBER CONNECTOR..........
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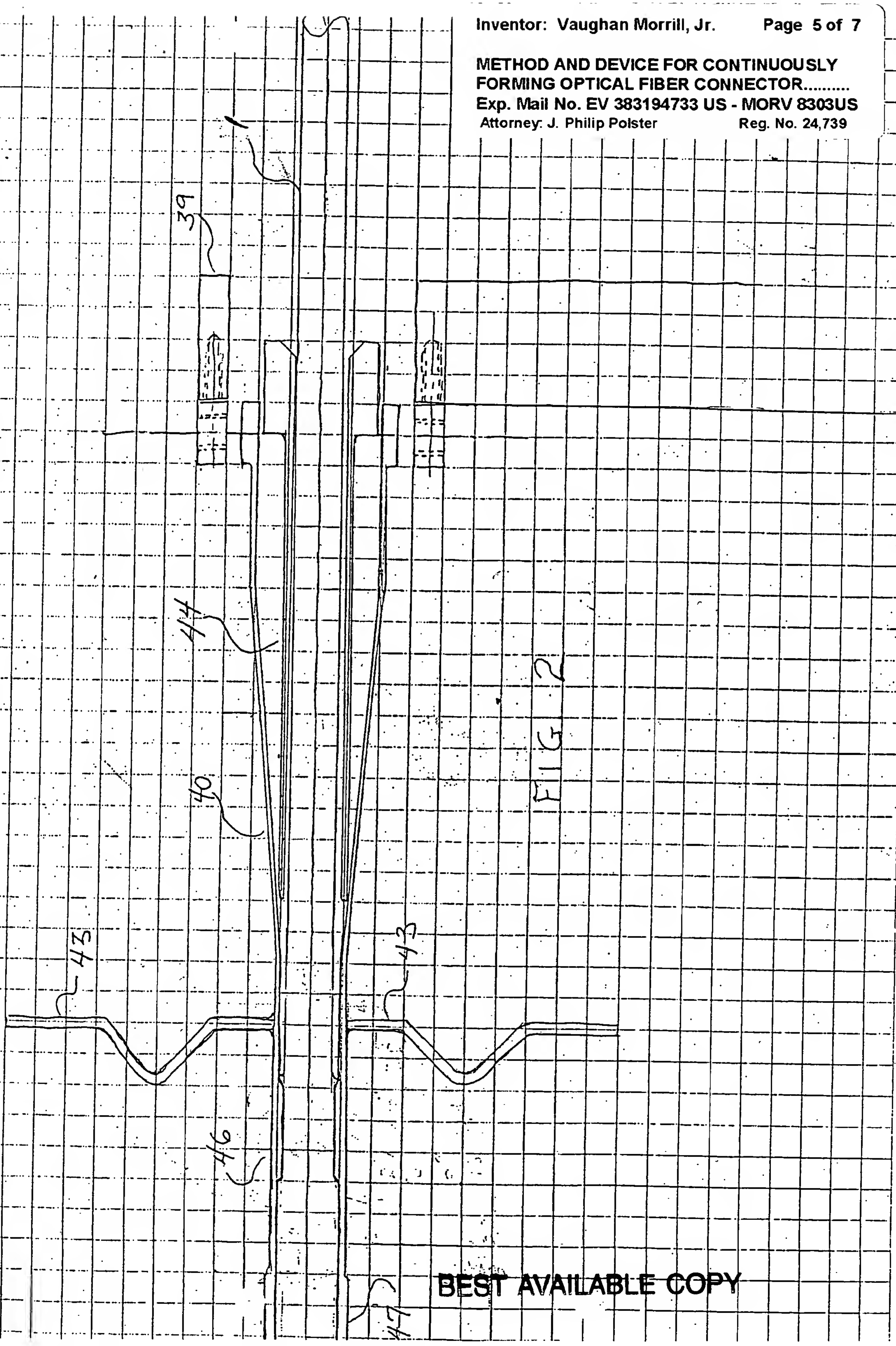
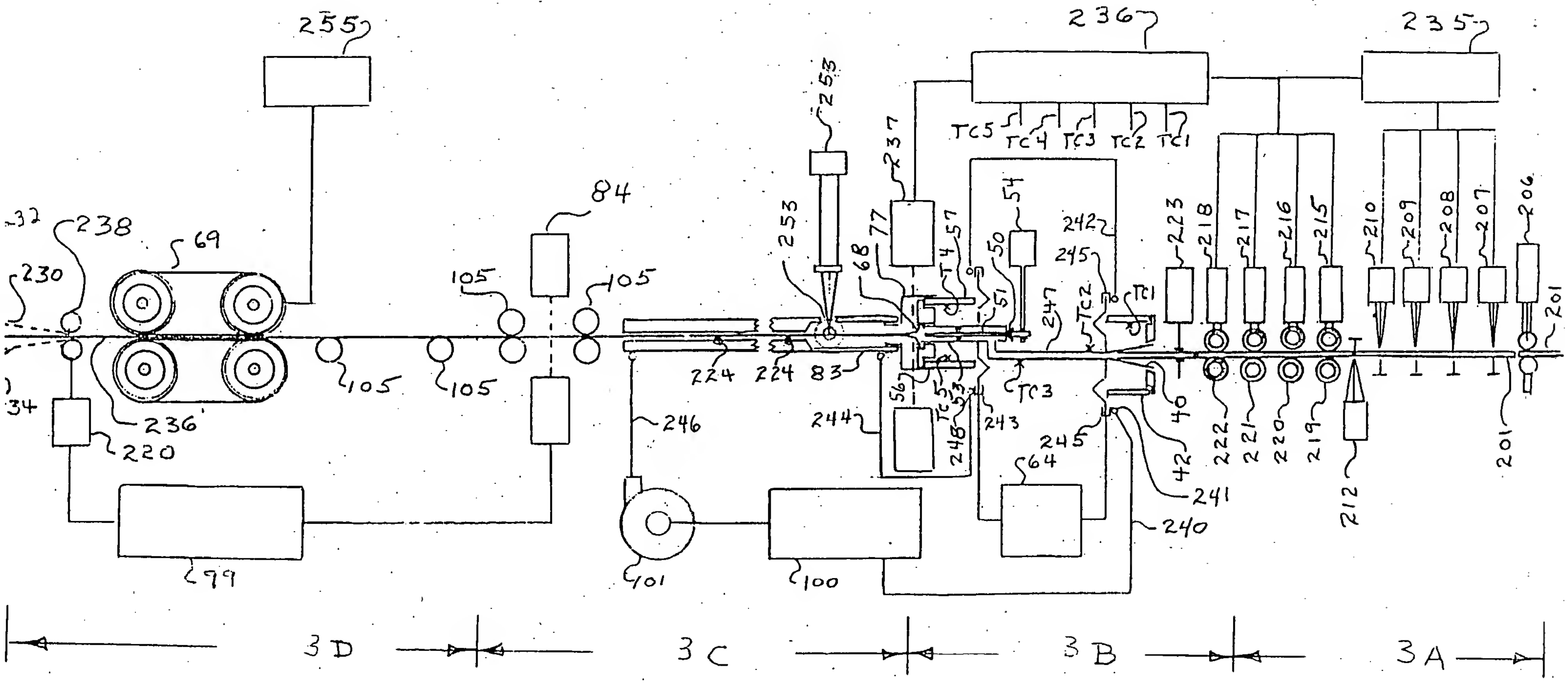



FIG 2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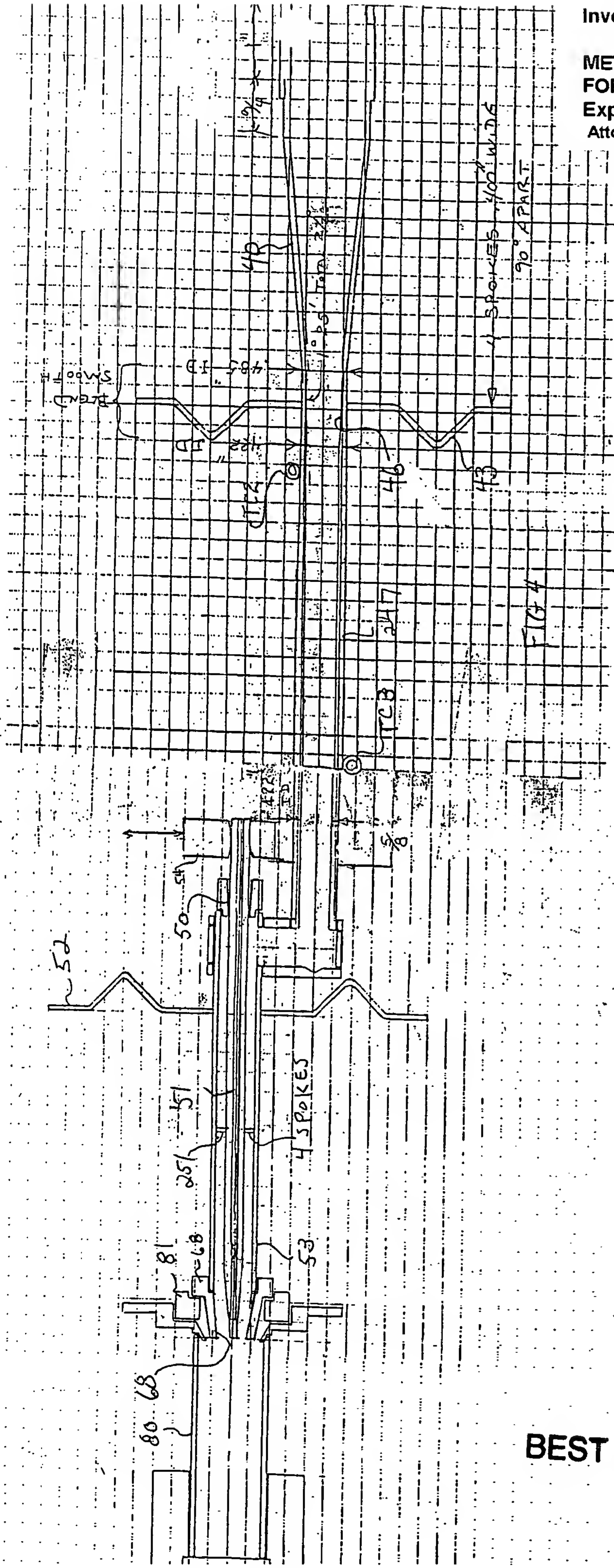


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*DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION*

As a below named inventor, I hereby declare that: My residence, post office address and citizenship are as stated below next to my name. I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled METHOD AND DEVICE FOR CONTINUOUSLY FORMING OPTICAL FIBER CONNECTOR GLASS AND OTHER CLOSE TOLERANCE COMPONENTS, the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above-identified specifications, including the claims.

I acknowledge the duty to disclose information, which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby appoint the following attorneys to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Philip B. Polster, Reg. No. 16,554, J. Philip Polster, Reg. No. 24,739, Lionel L. Lucchesi, Reg. No. 25,891, William G. Bruns, Reg. No. 19,541, Edward A. Boeschenstein, Reg. No. 22,986, William B. Cunningham, Jr., Reg. No. 26,155, Ralph B. Brick, Reg. No. 17,444, McPherson D. Moore, Reg. No. 28,449, J. Joseph Muller, Reg. No. 28,450, Jonathan P. Soifer, Reg. No. 34,932, Ned W. Randle, Reg. No. 35,989, Martha A. Michaels, Reg. No. 20,453, Mark E. Books, Reg. No. 40,918, Catherine W. Wall, Reg. No. 42,209, David H. Chervitz, Reg. No. 32,820, Ronald W. Hind, Reg. No. 24,643, Nelson D. Nolte, Reg. No. 42,938, Douglas D. Churovich, Reg. No. 50,613, Douglas E. Warren, Reg. No. 52,344, Ahaji K. Amos, Reg. No. 46,831 and Scott A. Smith, Reg. No. 46,067.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of Sole or First Inventor: Vaughan Morrill, Jr.

**Inventor's Signature:** ______________________ **Date:** _________

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